SUBJECT: CHEMISTRY

TITLE: The Relation Between the use of Detergents and the amount of Phosphate in Lake Water where we live.

RESEARCH QUESTION: Is there a relationship between the use of detergents and the concentartion of phosphate in lake water where I live by determining the concentration of phosphate using the colorimetric method?

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CONTENTS

THE RELATION BETWEEN THE USE OF DETERGENTS AND THE AMOUNT OF PHOSPHATE IN LAKE WATER WHERE WE LIVE

1. INTRODUCTION:

Phosphorus is significant for all living things. It has an important role in cell development and a key component of ATP (adenosine triphosphate) which acts as an energy carrier in living organisms. Phosphorus can be found in lots of compound forms such as phosphates. Phosphate (PO_4^{3-}) is an anion. The phosphate ion is found in many minerals in nature. For instance, phosphate is placed as calcium phosphate mineral in water. Phosphate is aimed to break down the dirt, that is why it places in cleaning products, mostly in surface active ones. For instance, some detergents contain sodium tripolyphosphate ($Na_5P_3O_{10}$). When the sodium tripolyphosphate ($Na_5P_3O_{10}$) enters the water, it pulls calcium and magnesium away, softening the water. By this way, phosphate makes the detergent to foam easily. Detergents are generally the most important contributors of phosphate of the water sources like lakes. The phosphate detergents used by human mix with water, contaminate the soil and then carried to the lake. In addition, plants need phosphate in order to grow and this is the reason that fertilizers contain phosphates. They are carried to lakes both by eroded soil particles and as dissolved form in underground water. There are other sources of phosphates such as chemical manufacturing and uncontrolled sewage runoff.

There are also some harm effects of phosphate. Especially, phosphate causes eutrophication. Eutrophication is one of the factors that decrease water quality. Excess in phosphates and nitrates decreases the dissolved oxygen in water. Mosses, algae and other plants in water sources grow and reproduce faster by using phosphates. When they die, they break down by the help of the bacteria, causing the oxygen in the water to decrease and oxygen deficiency causes aerobic organisms to die. In parallel with this, in anaerobic conditions, anaerobes,

cyanobacteria and algal blooms start to grow over the surface of the water. This causes an imbalanced green dirty view. This situation also affects other living organisms such as fish negatively. This results in a decrease in species biodiversity. Around the World, there are some examples that eutrophication occurs in some lakes. In Erie Lake; USA, Okeechobee Lake; Florida, Dianchi Lake; China, eutrophication exists. Those lakes may have sources which are mixing with drainage, waste waters which are mixed with fertilizers, there maybe fossil fuels wastes around the lake that come to the surface of the lake water.

On the other hand, the harmful effects of phosphates on water resources can be reduced. Testing the soil may be helpful to reduce the pollution by detecting the requirements of the soil. Using grassed waterways is a method to protect water resources. This reduces the soil erosion and decrease the amount of phosphate that reaches underground water. Also using natural cleaning products like; White vinegar, rock salt, sodium bicarbonate and lemons are used instead of phophate containing detergents. These are all can clean dirt, they are natural and friendly for the environment.

This study deals with the concentration of phosphates found in detergents, how these phosphates mixed with lake water and changes the concentration of phosphate in lake water. For these purposes, ammonium molybdate, thiourea and sulfuric acid solutions are used to convert phosphate in detergent and lake water samples to blue colored phosphomolybdate complex. Then the concentration of phosphate in ppm is determined by the use of colorimetric method in which the concentration and absorbance are directly proportional.

A literature method, Beer Lambert Law, a linear method that states the absorbance depends on the concentration of the material in a sample is used in this study. Law relates that the absorbance is dircetly propotional to the concentration of the solution and the lenght of the light path. The general Beer Lambert law is usually written as:

$A = a(lambda) \times b \times c$ [1]

A represents the measured absorbance, a (as lambda) is a wavelength dependent absorptivity coefficient, b is the path length, and c is the analyte concentration.

The detergent samples were chosen from the most sold and used detergents in the city where I live. There are two big lakes in our city which are the most important water ecosystems. The lakes were found to be the cleanest water in the lake in the past studies. But it has been observed that waste water is discharged from the city and surrounding facilities with high phosphate concentration.

There are some similar experiments that is done and one of them is to aimed to determine phosphate in water. A colorimetric method is done by Gilbert C. H. Stone and Joseph W. Goldzieher. They determined sodium in biological fluids and particularly in serum. Again, analyses of Fe is done by using colorimetric method by a chemistry proffesor at California State University.[2] In Nepal, phosphate in sugarcane juice, fertilizer, detergent and water samples by molybdenum blue method is done by Samjhana Pradhan and Megh Raj Pokhrel by using UV visible spectrometer. They used Beer Lambert's Law to find the concentration of the material in their samples, calculated the absorbance by the equation and showed them in the graphs.[3] Another experiment is done by David Gould.[4] He collected an unknown sample to determine the concentration of phosphorus in water by using UV-Vis spectrometer. He created a calibration curve to find out unknown concentration of phosphate by using its

[1] Beer-Lambert Law, life.nthu.edu.tw/~labcjw/BioPhyChem/Spectroscopy/beerslaw.htm.
[2] Libretexts. "Colorimetric Fe Analysis (Experiment)." *Chemistry LibreTexts*, National Science Foundation, 16 Dec. 2017, chem.libretexts.org/Ancillary_Materials/Laboratory_Experiments/Wet_Lab_Experiments/General_Chemistry_Labs/Colorimetric_Fe_Analysis_(Experiment).
[3] Pradhan, Samjhana, and Megh Raj Pokhrel. "Spectrophotometric Determination of Phosphate in Sugarcane Juice, Fertilizer, Detergent and Water Samples by Molybdenum Blue Method." The Initiation, www.nepjol.info/index.php/SW/article/view/9139
[4] "Determination of Phosphates in Water." Odinity, 17 Dec. 2017, www.odinity.com/determination-phosphates-water/.

absorbance. Other example is done by J. Heron had an aim to determine phosphate in water after storing it into polyethylene bottles. He examined that there was a decrement on the phosphate concentration and that is caused by the absorbance of the polyethylene. He related this to the bacterial actions. Again, Prof. Robert J. Lancashire made an experiment about the relationship between the intensity of color component and it's concentration by using the same method, spectrophotometer by using a water sample.[5]

2. METHOD

2.1 Research Question: Is there a relationship between the use of detergents and the concentartion of phosphate in lake water where I live by determining the concentration of phosphate using the colorimetric method?

2.2 Hypothesis: There is a relationship between the use of detergents and the amount of phosphate in lake water where we live, the phosphate concentration increases by the usage of the detergents and then mixes with the lake waters.

2.3 Variables

2.3.1 Dependent Variable: Concentration of phosphate in ppm which is calculated by determining the absorbance of detergents and lake water samples that are measured by Vernier Lab Quest Colorimeter.

2.3.2 Independent Variable: The type of samples that are collected from the most known two different lakes which are known as mixed with different water wastes in the place I live and detergents that are mostly used in my city.

[5] Lancashire, Robert John. Unit - Chemistry of Textiles: Tanning of Leather, wwwchem.uwimona.edu.jm/lab_manuals/c10expt36.html.

2.3.3 Controlled variables : Room temperature; the ventilation isn't worked during the study and the experiment is done in the same room which is at 22 ^{0}C, room pressure is kept constant and the value for the room pressure was 912.5 kPa, the method was same to determine the concentration of phosphate in my samples, same ammonium molybdate, thiourea and sulfuric acid solutions are used. The same colorimeter is used during the experiment.

2.4 Materials and Equipment:

- 1.714 grams of Ammonium molybdate ($[NH_4]6Mo_7O_{24}.4H_2O$).
- 1 Molar Sulfuric Acid Solution (H_2SO_4), 1 L
- 10 grams of Thiourea (CH_4N_2S)
- 5 grams of 5 different branded detergents samples
- 5 Porcelain crucibles and lids
- Two different 1 liter water samples that are collected from two lakes
- 7 Whatmann 41 filter Papers
- Electronic balance ± 0.001
- Distilled Water
- 5 x 250 ml Glass Beakers
- 9 x 250 ml Volumetric Flasks
- 1 x 500 ml Volumetric Flask
- 7 Erlenmeyer Flasks
- 7 glass funnels
- Bunsen burner and tripod
- 1 Stirring rod
- Spatula
- Weighing container

- Vernier Lab Quest and colorimeter
- 50 ml Graduated Cylinder

2.5 Procedure:

2.5.1 Preparation of Ammonium Molybdate ($[NH_4]6Mo_7O_{24}.4H_2O$) Solution:

Weigh out; 1.714 grams of ammonium molybdate ($[NH_4]6Mo_7O_{24}.4H_2O$). Put it into 250 ml of volumetric flask and add 150 ml of warm water to dissolve the solid until a slightly, milky solution will be observed. Then, cool this solution in the room temperature and dilute it to the mark line on the flask with distilled water.

2.5.2 Preparation Thiourea (CH_4N_2S) solution:

Weigh out 10 grams of thiourea and place it into 500 ml of a volumetric flask. Then, dissolve it by adding 50 ml of distilled water. add distilled water to the marked line on the flask.

2.5.3 Preparation of 0.125 M Sulfuric Acid (H_2SO_4) Solution:

Measure 31.25 ml of 1M Sulfuric Acid (H_2SO_4) solution, put it into a 250 ml of a volumetric flask and add distilled water to the markline on the flask.

2.5.4 Preparation of Detergent samples:

For the detergent samples, scale five grams of each different branded detergents. Put the weighing container on the balance and tare it. Use the spatula to put the detergent into the weighing container. After that, transfer each detergent sample into a porcelain crucible and label them as 1, 2, 3, 4 and 5. For the heating process, place each porcelain crucible on a tripod and burn the bunsen burner. Heat each sample for 30 minutes until all of them are burned and become black ashes. Place the ashes into separate 250 ml of beakers and add 50

ml of water to each one. Rinse the crucibles with distilled water to be sure that all the ash is transfered to the beaker. Then add 1 M sulfuric acid solution into each beaker until the ashes are completely dissolved. Wait each detergent sample in water bath at 30 °C for 10 minutes. Take a filter paper, fold into half and then in half again. Wet the filter paper with a few drops of distilled water and place into a funnel. Place the funnel into the neck of an erlenmeyer flask, pour the mixture through the funnel. Repeat the filtration procedure for each detergent sample and label them as 1, 2, 3, 4 and 5. Measure 2 ml of your first detergent sample, put it into a 250 ml of a volumetric flask, add 5 ml of ammonium molybdate solution, 5 ml of 0.125 M H_2SO_4 solution and 10 ml of thiourea solution. Wait 10 minutes and add distilled water to markline on the flask. Label it as 1. Repeat this procedure for other detergent samples. To measure the absorbance use Vernier Lab Quest colorimeter. There are little plastic cuvettes beside the colorimeter. Take one of them and flush them before the usage. Prior to measurement, set the wavelength to 635 nm. Then calibrate the colorimeter by placing distilled water in a cuvette and then by pressing ‘Cal’ on the colorimeter.

Take a cuvette and fill about 3/4 of it with your final detergent sample. Put the filled cuvette and place it into the colorimeter so that the clear faces of the cuvette are in the light path. (it is important that the measurement is made after ten minutes of the preparation of the complexes) Close the cap of the colorimeter. Wait until the value of the wavelength reach a certain value and stay at that value, note the value. After each measurement, zero the absorbance. For each detergent sample, repeat the procedure for 5 times.

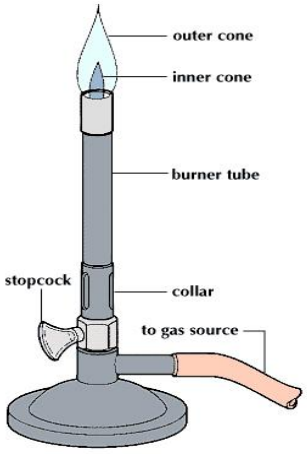


Figure 1: A Bunsen burner.

Figure 2: A Vernier colorimeter.[6]

2.5.5 Preparation of the Lake Water

Filter your lake water samples into separate 100 ml of beakers by constructing filtration mechanism as done in detergent samples. Measure 2 ml of one of your lake water samples, put it into a 250 ml of a volumetric flask, add 5 ml of ammonium molybdate solution, 5 ml of 0.125 M H_2SO_4 solution and 10 ml of thiourea solution. Wait 10 minutes and add distilled water to the markline on the flask. Label it as A. Repeat the same procedure for other lake water sample and label it as B. Measure absorbance of each sample as done in detergent samples for 5 times.

[6] School Savers - Vernier COL-BTA Colorimeter, www.schoolsavers.com/Vernier-COL-BTA-Colorimeter-P511C98.aspx.

3. DATA COLLECTION & PROCESSING

3.1 Qualitative Data:

First of all, while burning the detergents, the powder of the detergents blowed and became a color between grey and black. After the burning process of the each detergent sample look like a sponge. Two out of five detergent samples were observed like an ash and one of them was like tar, that collapsed in the crucible. After that, when sulfuric acid is added into each detergent sample shortly after they are filtrated, the detergent complex is rised and bubbled. Then, solutions became light blue because of the phosphomolybdate complex formed after the addition of ammonium molybdate, thiourea and sulfuric acid solutions.

Figure 3: Burning of a detergent sample by using Bunsen burner.

Figure 4: Burned detergent sample that became ash by using Bunsen burner.

Figure 4: Filltration setup of detergent samples.

3.2 Quantitative Data:

Detergent Samples	Detergent masses in grams
1	5.006 grams ±0.001
2	5.033 grams ±0.001
3	5.044 grams ±0.001
4	5.011 grams ±0.001
5	5.012 grams ±0.001

Table 1: The mass of detergent samples in grams of the five different detergent at the beginning of the investigation.

Absorbance ±0.001					
Detergent Samples:	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
1	0.110	0.113	0.111	0.108	0.115
2	0.088	0.091	0.090	0.095	0.095
3	0.124	0.123	0.131	0.126	0.121
4	0.096	0.086	0.083	0.093	0.090
5	0.164	0.166	0.167	0.167	0.168

Table 2: Measured absorbance of the five different detergent samples by using colorimeter.

Absorbance ±0.001					
Water Samples:	Trial1	Trial 2	Trial 3	Trial 4	Trial 5
Lake A	0.064	0.062	0.062	0.060	0.061
Lake B	0.052	0.052	0.050	0.050	0.052

Table 3: Measured absorbance of the two different lake water samples by using colorimeter.

3.3 Processing the Quantitative Data

The concentration of phosphate in detergent and water samples are found in ppm by using the following equation:

The equation is: $y = 0.0126x + 0.0135$

'x' is the concentration in ppm of phosphate in the samples, 'y' is the absorbance of the samples that are measured by the Vernier colorimeter.

The given equation is from a spectrophotometric determination of phosphate in soil, detergents, water, bone and food samples through the formation of phosphomolybdate

solution investigation which is done by B. Shyla, Mahadevainah and G. Nagendrappa.[7] This equaiton is used because in this study, there wasn't a calibration curve so in the reference investigation, from the calibration curve that is already obtained is used.

Detergent sample 1 of Trial 1: Example calculation of the concentration of phosphate in ppm:

$0.110 = 0.0126x + 0.0135$

$0.110 – 0.0135 \div 0.0126 = 7.66$

Uncertainity Calculation:

Example % uncertainity calculation for Detergent sample 1 of Trial 1:

Measured absorbance for detergent 1 trial 1: 0.110

Uncertainity of the colorimeter: 0.001

$0.001 \div 0.110 \times 100 = 0.91\%$

[7] "Explore Scientific, Technical and Medical Research on ScienceDirect." Neurolmage, Academic Press, www.sciencedirect.com/.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Detergent 1	7.66 ±0.9%	7.89 ±0.9%	7.74 ±0.9%	7.50 ±0.9%	8.06 ±0.9%
Detergent 2	5.91 ±1%	6.15 ±1%	6.07 ±1%	6.47 ±1%	6.47 ±1%
Detergent 3	8.77 ±0.8%	8.69 ±0.8%	9.33 ±0.8%	8.93 ±0.8%	8.53 ±0.8%
Detergent 4	6.55 ±1%	5.75 ±1.%	5.52 ±1%	6.31 ±1%	6.07 ±1%
Detergent 5	11.9 ±0.6%	12.1 ±0.6%	12.2 ±0.6%	12.5 ±0.6%	12.3 ±0.6%
Lake A	4.01 ±2%	3.85 ±2%	3.85 ±2%	3.69 ±2%	3.77 ±2%
Lake B	3.05 ±2%	3.05 ±2%	2.89 ±2%	2.89 ± 2%	3.05 ±2%

Table 4: Table of the calculated concentration of PO_4^{3-} ion in ppm samples for each trial of the detergent samples and lake water.

Mean of Detergent sample 1 of Trial 1:

(7.66 + 7.89 + 7.74 + 7.50 + 8.06)/5 = 7.77

Unceratinity Calculation For Means:

$X_{max} - X_{min} \div 2 \sqrt{n}$

X_{max} is the maximum value of the samples in the Table 6.

X_{min} is the minimum value of the samples in the Table 6.

n is the trial number as 5.

Example uncertainity calculation of the mean of Detergent sample 1 of Trial 1:

X_{max}: 8.06

X_{min}: 7.50

$8.06 – 7.50 \div 2\sqrt{5} = 1.74$

Samples	Means
Detergent 1	7.77 ± 2.00
Detergent 2	6.21 ±0.60
Detergent 3	8.85 ±0.90
Detergent 4	6.04 ±1.00
Detergent 5	12.14 ±0.50
Lake A	3.83 ±0.40
Lake B	2.99 ±0.20

Table 5: Means are calculated for the ppm concenration of PO_4^{3-} ion from the table 4 and their uncertainities are calculated by using the data from the table 4 for each sample.

Error Calculation:

In the invesion, there wasn't a theoratical value so standard error is calculated. For the standard error, standard deviation is calculated firs. Then divided by $2\sqrt{5}$.

Example standard error calculation for detergent 1:

$$\mathrm{SD} = \sqrt{\frac{\sum |x - \bar{x}|^2}{n}}$$

[8]

x: the each trial dataset in the Table 4.

$\bar{x}$: the means in the Table 5.

n : is the number of trials; 5

$\sum (xi - \bar{x})^2$: The sum of $(xi - \bar{x})^2$ for all data.

Standard Error: SD ÷ $2\sqrt{n}$

n: number of trials so n is 5 again.

Example standard deviation calculation for Detergent sample 1:

$\bar{x}$: 7.77

$\sqrt{(7.66-7.77)^2 + (7.89-7.77)^2 + (7.74-7.77)^2 + (7.5-7.77)^2 + (8.06-7.77)^2 \div 5} = 0.19$

$0.19 \div 2\sqrt{5} = 0.215$

[8] Calculating Standard Deviation Step by Step." Khan Academy, Khan Academy, www.khanacademy.org/math/probability/data-distributions-a1/summarizing-spread-distributions/a/calculating-standard-deviation-step-by-step.

	Standard Error
Detergent 1	0.215
Detergent 2	0.249
Detergent 3	0.305
Detergent 4	0.415
Detergent 5	0.152
Lake A	0.119
Lake B	0.088

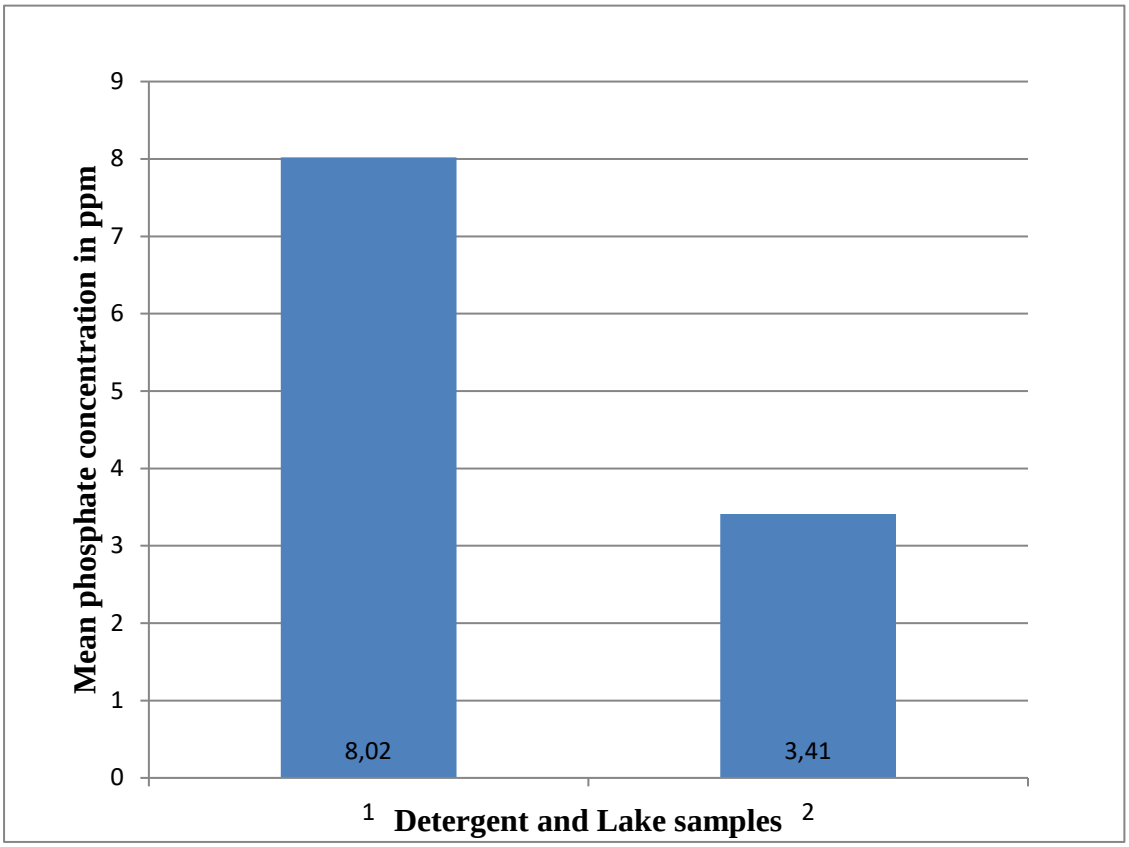
Table 7: Standard error is calculated for detergents and lake waters.

The mean calculation of the phosphate concentration in ppm of the detergents 1,2,3,4 and 5 :

(7.77 + 6.21 + 8.85 + 6.04 + 12.14) ÷ 5 = 8.2

The mean calculation of the phosphate concentration in ppm of the lakes A and B:

(3.83 + 2.99) ÷ 2 = 3.4



Graph 1: Graph of the mean phosphate concentration in ppm. The column 1 represents the mean of the phosphate concentration in ppm of the detergents 1, 2, 3, 4 and 5. The column 2 represents the mean of the phosphate concentration in ppm of the lake waters A and B.

4. CONCLUSION & EVALUATION:

Phosphates in the water sources like lakes come from different sources as mentioned before from fertilizers and detergents. When they mix to the lake water, they cause eutrophication. In this study, the relation between the concentration of phosphate ion in detergents and the concentration of phosphate ion in lake water is investigated. Five different branded detergents are involved and their absorbances are measured by using Vernier colorimeter. By determining absorbances, the concentration of phosphate in terms of ppm is found by using the equation from the study of the spectrophotometric determination of phosphate in soil, detergents, water, bone and food samples through the formation of phosphomolybdate solution which is done by B. Shyla, Mahadevainah and G. Nagendrappa and the relation between the phosphate in detergents and the phosphate that comes from the detergents to lake water is interrelated and showed in a bar graph. The results showed that phosphate found in detergents was very high. Between the detergent samples detergent 5 and between the lakes, lake A have the most phosphate concentration.

The early investigations showed that phosphate concentration in terms of ppm in a clean lake at normal conditions which is not a mix of drainage or waste water is between 0.05 and 0.20 ppm.[9] In the present investigation, the phosphate concentration of the two lakes are 3.83 and 2.99. The results are higher than a normal clean lake water. This is why the lakes which are selected for the study are both mixing with different water wastes such as sewage and merge in the lakes which have phosphate inside. This justifies my hypothesis which states that detergents contain a high phophate concetration and the waste water that is mixed with lakes increases the phosphate concentration in them.

[9]Accumulation of Phosphates in Water." ACS Publications, pubs.acs.org/doi/abs/10.1021/jf60171a004?journalCode=jafcau.

The highest standard deviation is determined for the detergent 4 and the lowest standard deviation is calculated for lake A. So it can be rumored that the smallest standard error values are calculated for the lakes. For all detergent samples and the lake samples, the uncertainty values are bigger than the standard errors. The uncertainty for the detergent 2 is 2 and the error is 0.215, for detergent 2; uncertainty is 0.60 and error is 0.249, for detergent 3; 0.90-0.305, detergent 4; 1-0.415, the uncertainty for detergent 5 is 0.50 and the error is 0.152. For the lake samples, the uncertainties are 0.40 and 0.20 and the error values 0.119 and 0.088 respectively for both of them. Again, this shows that there is random error present for both the detergent samples and the lake samples beacuse uncertainity values are bigger than the errors. Random error arises from the uncertainties in the precise measuring instruments such graduated cylinder, colorimeter, precision balance. In order to minimize random errors, repeated measurments (5 trials for each detergent and water samples) were taken to obtain an average concentration of PO_4^{-3} in ppm. Using pipette or burette instead of graduated cylinder when preparing solutions will be better because the measurment that is done by a pippette or burette is more precise. It is better if the UV visible spectrophotometer is used in the experiment, to have more accurate results but there wasn't a UV visible spectrophotometer in the laboratory to measure the absorbance, there was Vernier Lab Quest colorimeter, so colorimeter and it's highest wavelenght is selected to measure the absorbance. The maximum wavelength on the colorimeter is 650 nm. The phosphomolybdate complex solution have its maximum absorbance at 840. The colorimeter that is used measures absorbance of specific colors. But UV visible spectrometer measures transmittance as a function of wavelength. The maximum wavelength is used in the study because of the conditions. While doing the experiment, the loss of matter from detergents while burning them and transferring them into beakers cause systematic errors. In addition, using an oven which can be heated to 350 ^{0}C instead of heating of detergent samples on bunsen burner gives more accurate results. In the

oven all detergents could be converted to ashes easily. Also while calibrating the colorimeter, maybe I forget to press ‘cal’ in some of the trials. Conventionally, in colorimetric anaylsis standard solutions containing the analyte are prepared, their absorbances are measured and data is plotted to obtain a graph of absorbance versus concentration. In this study, a calibration curve wasn’t plotted. Instead, the equation of the best line of abrosbance versus concentration of phosphate in ppm is used from the investigation which is done by B. Shyla, Mahadevainah and G. Nagendrappa. It is better to draw the calibration graph by using standard phophate solutions to determine the phosphate concentartion in detergent and lake samples.

Five different branded detergents and two different lake samples are collected and used in the experiment. The lake sources was limited in the town where I live so I only collect two different lake water samples. More different detergents and lake water samples can be used for better comparison. Limited sources limit and affect the comparison. Some other materials such as fertilizers also contain phosphate. These different materials can be investigated in terms of phosphate concentration. Using a high temperature oven and UV visible spectrophotometer will be more proper and should be used in the future investigations.

REFERENCES:

1. BeerLamber,Law,life.nthu.edu.tw/~labcjw/BioPhyChem/Spectroscopy/beerslaw.htm.
2. Libretexts. “Colorimetric Fe Analysis (Experiment).” Chemistry LibreTexts, National Science Foundation, 16 Dec. 2017, chem.libretexts.org/Ancillary_Materials/Laboratory_Experiments/Wet_Lab_Experiments/General_Chemistry_Labs/Colorimetric_Fe_Analysis_(Experiment).
3. Pradhan, Samjhana, and Megh Raj Pokhrel. “Spectrophotometric Determination of Phosphate in Sugarcane Juice, Fertilizer, Detergent and Water Samples by Molybdenum Blue Method.” The Initiation, www.nepjol.info/index.php/SW/article/view/9139.
4. “Determination of Phosphates in Water.” Odinity, 17 Dec. 2017, www.odinity.com/determination-phosphates-water/.
5. Lancashire, Robert John. Unit - Chemistry of Textiles: Tanning of Leather, wwwchem.uwimona.edu.jm/lab_manuals/c10expt36.html.
6. School Savers - Vernier COL-BTA Colorimeter, www.schoolsavers.com/Vernier-COL-BTA-Colorimeter-P511C98.aspx
7. “Explore Scientific, Technical and Medical Research on ScienceDirect.” Neurolmage, Academic Press, www.sciencedirect.com/.
8. Calculating Standard Deviation Step by Step.” Khan Academy, Khan Academy, www.khanacademy.org/math/probability/data-distributions-a1/summarizing-spread-distributions/a/calculating-standard-deviation-step-by-step.
9. Accumulation of Phosphates in Water.” ACS Publications, pubs.acs.org/doi/abs/10.1021/jf60171a004?journalCode=jafcau.